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Saskatchewan Agriculture, Food and Rural Revitalization

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FINAL REPORT

20000272

LANDSCAPE LEVEL VARIATION IN RECOVERY OF PRODUCTION IN NATIVE RANGELAND AFTER GRAZING

Funded by: The Agriculture Development Fund

March, 2005
Prepared by: University of Saskatchewan

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Landscape Level Variation in Recovery of Production of Native Rangeland After Grazing

Funded by:
Saskatchewan Agriculture Development Fund
Project-20000272

Final Report
For the Period of
2 February 2001—15 February 2005

J.T. Romo, Project Leader
and
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Department of Plant Sciences
University of Saskatchewan

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Abstract

Studies were conducted in the Northern Mixed Prairie range type on a Loamy Range Site in excellent ecological condition in the Dark Brown Soil Zone of central Saskatchewan to determine the amount of time needed by Agropyron dasystachyum/A. smithii, Festuca hallii, Stipa curtiseta, "other" graminoids (all graminoids except the previous 3 species), forbs and shrubs and total standing crop to recover their forage production potential following mowing. In June, July and August, regrowth for the 6 species or plant groups and soil water at the 0 to 30 cm depth was determined following a single mowing of the sward to a 7.5 cm stubble height in May, June, July, August, September, October, November or April on 5 landform elements including north aspect- concave slope, north aspect- convex slope, south aspect- concave slope, south aspect- co standing crop or above ground net primary production (ANPP). Instead, mowing generally reduced current year production and AN PP. Depending on month of mowing, species or species groups and landform elements, 1 to 25 months elapsed from mowing until current year standing crop was similar ($P< 0.05$) to that in the unmowed control. Recovery of production after mowing suggests that a rotation or deferred rotation grazing system would be needed to maintain forage production by Agropyron dasystachyum/A. smithii, Stipa curtiseta, forbs and shrubs, and "other" graminoids. However, it would appear that grazing systems that incorporate 1 full year of rest after grazing are needed to maintain potential production of Festuca hallii and total forage production over the entire landscape. These documented responses of plant recovery after herbage removal can be used to develop grazing systems that sustain forage production.

Executive Summary

Grazing forages can be the most sustainable agricultural practice, and it is the most economical method of value-added processing of forages in Saskatchewan. However, to realize sustainable use and peak efficiency of value-added production on an acre-by-acre and day-by-day basis, plants must be given time to regrow and recover their vigour after grazing. The importance of providing adequate rest after forage removal is well understood and applied by managers of forages that are used for hay. In this instance, a conscious decision is made to allow plants adequate rest or the opportunity to complete their growth between haying operations to maintain plant vigor and to ensure that maximum quality and quantity of forage are produced and harvested on each acre and in time. However, even though this principle of allowing plants to complete their growth would be equally advantageous to apply in grazing systems, few pasture mangers have capitalized on this opportunity. The lack of application of this principle of rest after grazing is largely attributed to the scarcity of information for forages other than those used for hay or green feed. If the rest period for forages is not long enough following grazing, plant vigour is diminished, forage production declines, and this decline triggers a cascading reduction in the efficiency of beef production, reducing sustainability. Conversely forage and livestock production can only be maximized and sustained if forages are given adequate rest after grazing.

Studies were conducted in the Northern Mixed Prairie range type on a Loamy Range Site in excellent ecological condition in the Dark Brown Soil Zone of central Saskatchewan to determine the amount of time needed by key forage species to recover their production potential following grazing. Forage production and current year standing crop following mowing to a 7.5 cm stubble height in May, June, July, August, September, October, November and April was determined for *Agropyron dasystachyum/A. smithii*, *Festuca hallii*, *Stipa curtiseta*, forbs and shrubs, graminoids (excluding *Agropyron dasystachyum/A. smithii*, *Festuca hallii* and *Stipa curtiseta*), and total phytomass (all species and species groups combined) on north aspect-concave slope, north aspect-convex slope, south aspect-concave slope, south aspect-convex slope and level upland landform elements over a 3-year period.

Current year standing crop of *Agropyron dasystachyum/A. smithii*, *Festuca hallii*, *Stipa curtiseta*, forbs and shrubs, graminoids, and total phytomass (all species and species groups combined) varied among dates of mowing and landform elements. In some cases the production potential of plants recovered in the year of mowing, in other cases plant production potential recovered the growing season following mowing, and in other instances the potential production of plants did not completely recover until the second full growing season after mowing. The time between mowing and the first of at least 2 consecutive months in which current year standing crop of *Agropyron dasystachyum/A. smithii* was not different ($P \leq 0.05$) from the unmowed control ranged from 1 to 13 months. Current year standing crop of *Stipa curtiseta* was not different ($P \leq 0.05$) from the unmowed control 1 to 12 months after mowing. Twelve months or less were needed for current year standing crop of other graminoids and forbs and shrubs to become similar ($P \leq 0.05$) to the unmowed control. Up to 25 months elapsed between mowing until the month that current year standing crop for *Festuca hallii* and total current year standing crop were not different ($P \leq 0.05$) from the unmowed control.

Sustainable grazing of the Northern Mixed Prairie range type in central Saskatchewan requires complete rest from grazing if potential forage production is to be realized and overgrazing is to be prevented over the entire landscape. The results of this research can be used as guidelines for developing economically and ecologically sustainable grazing systems.

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This progress report contains results on research that was funded by **Saskatchewan Agriculture Development Fund. Project 20000272.** Our gratitude is extended to **ADF** for research funding without which it would not be possible to conduct this study. The Greencover Canada Technical Assistance Component also provided funding that allowed completion of this project. Thanks are extended to Mr. Ron Dunning of Macrorie, Saskatchewan for allowing studies to be conducted on his property. Andrew Pantel has provided exceptional assistance and leadership in all phases of the study. The excellent assistance of Margaret Ryan, Bin Xu, Mohammad Akhgar, Stephanie Bone, Renny Grilz, Holly Kayln, Jie Qiu, Tara Sample, Yanchun Su, Yu Rong Wu, Lacey Field, Amy Logan, Dale Gross, Maryam Akhgar, Janan Gopalakrishman, Jeffrey Gu, Crystal Hinz, Paul Kounine, Kaylee Poulin, Zhaohui Wei, Dong Wang, Rensong Liu, Kaitlin Weichel and Judy Haraldson in the field and laboratory is most appreciated. Dr. Dan Pennock of the University of Saskatchewan provided useful discussions for assisting in identifying landform elements and additional advice on experimental considerations.

Introduction

A goal of Saskatchewan Agriculture, Food and Rural Revitalization is to increase cattle production in the province. Short- and long-term challenges to meeting this goal will be sustainable production of inexpensive and high quality forage while maintaining environmental quality. Meeting these goals requires information that can be provided to producers to enable them to increase and sustain forage production. About 25-40% of the rangeland in southern Saskatchewan is in good or excellent condition (Zhang and Romo 1994, 1995). Increasing the condition of the remaining forage resource (60-75%) on native rangeland to good or excellent condition would translate into a 25-50% increase in grazing capacity on rangelands of Saskatchewan. This increase in grazing capacity can be achieved and sustained only by improving management and implementing grazing systems that match the needs for growth of forages. The key to realizing increased and sustained grazing capacity is to provide forages with adequate rest following grazing.

Grazing systems should simply involve alternating periods of use with periods of rest (Romo 2001). Resting plants after grazing is a fundamental requirement that must be incorporated into grazing management to increase or maintain forage production. Ironically, despite knowledge that resting plants after grazing is important, few studies have addressed this issue. Recent studies (Harrison and Romo 1994, Romo *et al.* 1995, Kowalenko and Romo 1998a,b, Romo and Harrison 1999) revealed a wide range in the amount of time required by plants to recover their production potential after grazing. Rangelands are composed of many landform elements and growth of plants varies among range sites (Abouguendia 1990), aspects (Ayyad and Dix 1964) and topography (Klemmendson 1964). Presumably plants recover their production potential at different rates after grazing, depending on landform characteristics.

Limited productivity of forages is a bottleneck in producing beef that may be circumvented by improved grazing management. Factors limiting forage production must, however, be isolated so proper grazing management prescriptions can be made. The upper limits to beef production are ultimately determined by forage production. The present research was designed to provide range managers with fundamental knowledge of rest requirements of native plants after grazing which in turn can be used to develop grazing systems that are economically and ecologically sustainable.

Project Objectives

The objectives of this research were to determine the effects of different months of mowing on the regrowth of native plants on different landform elements in the Mixed Prairie of Saskatchewan on: 1) forage production by native plants, and 2) the number of months needed by native forage plants to regain their forage production potential after mowing.

Materials and Methods

Research was conducted in the Coteau Hills Landform Area of the Mixed Grassland Ecoregion of central Saskatchewan (Figure 1)(Acton *et al.* 1998). The study site was located about 20 km south of Macrorie, Saskatchewan; the legal location is the $SW^{1/4}$, Section 20, Township 26, Range 9, West of the 3rd meridian. Soils of this knob-and-kettle landscape are transitional Brown and Dark Brown, and is classified as a Calcareous, Dark Brown

Figure 1. Oblique air photo of the study site that was located in the Coteau Hills Landform Area of the Mixed Grassland Ecoregion of central Saskatchewan. Note the plots throughout this knob-and-kettle landscape.

Chernozem of the Weyburn Association (Ellis *et al.* 1970). The range site is Loamy (Abouguendia 1990), and vegetation of this Northern Mixed Prairie range type was in excellent ecological condition (Abouguendia 1990) because the site had not been grazed for many years before conducting this study.

The experimental design was a randomized-complete-block with 4 replicates of 5 landform elements and 9 months of mowing. The experiment was repeated in time on another set of 4 replicate plots for a total of 8 replicates for each month of mowing and landform element. Plant growth after mowing was determined for 6 species or plant groups on north aspect-concave slope, north aspect-convex slope, south aspect-concave slope, south aspect-convex slope and level upland landform elements after mowing in April, May, June, July, August, September, October or November. Unmowed control plots were also included in each replicate of each landform element.

Four catenas were selected in the study area as replicates for imposing mowing treatments in 2001-2002 and another set of 4 replicates was established for mowing treatments that were imposed in 2002-2003. Each catena was divided into north and south aspects, and easily identified, 3-dimensional landform elements were delineated within each aspect (Pennock *et al.* 1987). Plots on northerly aspects averaged 19° west from true north while plots on southerly aspects averaged 10° west from true south (Table 1). Concave and convex landform elements were identified within north and south aspects. Slopes on this hummocky landscape average 10 to 15% (Ellis *et al.* 1970). A level uplands landform element with less

Table 1. Total canopy cover of plants (excluding litter), species richness, the Shannon-Weiner diversity index and the aspect of landform elements for plant communities in control plots on the 5 landform elements.

Aspect and landform element	Total canopy cover (%)	Richness (Species in 16 m^2)	Shannon-Weiner diversity index (H')	Landform element aspect (°)[1]
North aspect -Concave slope	56	54	2.52	338°
North aspect -Convex slope	56	58	2.47	342
South aspect -Concave slope	51	52	2.60	188
South aspect -Convex slope	52	49	2.78	191
Level Upland	40	32	2.13	---

[1] 90-270° is southerly aspect; 0-90° and 270-360° is northerly aspect

than 5% slope was also identified for a total of 5 landform elements. In each replicate landform element, an 18 by 20 m block was established. Each block was further subdivided into 9 plots that were 2 by 20 m in size. The 2 by 20 m plots were oriented parallel to the slope gradient in each landform element.

In 2001 and 2002, 20-20 by 50 cm quadrats were located at 1 m intervals in the control plot for each landform element and replicate. Canopy cover of each plant species, bare ground and litter was recorded in each quadrat using the procedure of Daubenmire (1959). Cover data from the 20 quadrats in each plot were converted to percentage values (Daubenmire 1959) and averaged over the 8 replicates. Plant taxonomy follows Looman and Best (1987). Species richness and the Shannon-Weiner diversity index were calculated for each landform element using PC-ORD, a statistical package for ecological data (McCune and Mefford 1999). Hierarchical cluster analysis was used to group plant communities on the landform elements (McCune and Mefford 1999).

Total canopy over of plants ranged from 40 to 56% (Table 1) and species richness varied from 32 to 58 species in each 16 m^2 on the 5-landform elements (Table 1). The Shannon-Weiner diversity index ranged from 2.13 to 2.60 (Table 1). *Festuca hallii* (Vasey) Piper, *Stipa curtiseta* Hitchc. and *Agropyron dasystachyum* (Hook.) Scribn. dominated north aspect-concave slope and north aspect-convex slope landform elements (Table 2). The south aspect-concave slope landform element was dominated by *Stipa curtiseta* and *Festuca hallii*. *Stipa curtiseta*, *Agropyron dasystachyum* and *Carex* sp. dominated the south aspect-convex slope landform element while *Stipa curtiseta* and *Agropyron dasystachyum* were the most abundant plants on level uplands. Hierarchical cluster analysis using canopy cover of plants indicated that the plant communities on south aspect-concave slope, level uplands and south aspect-convex slope were similar as were communities on landform elements on north aspects (Figure 2).

Plots were mowed once to a height of about 7.5 cm and the plant material cut by mowing was removed from the plots. Each plot was subdivided into 4 sections that were 5 m in length, and 1–50 by 50 cm quadrat was randomly located within each section of the plot and clipped to ground level to determine the amount of phytomass remaining after mowing. The amount of current year standing crop removed by mowing ranged from 67% to 84% and averaged 76% in May, 78% in June and July, and 79% in August (Table 3). Locations where quadrats were clipped were not sampled again. Standing crop of plants following mowing was determined in replicates 1 through 4 by clipping plants at ground level in June, July and August 2001, 2002 and 2003 in 1-50 by 50 cm (0.25 m^2) quadrat that was randomly located in

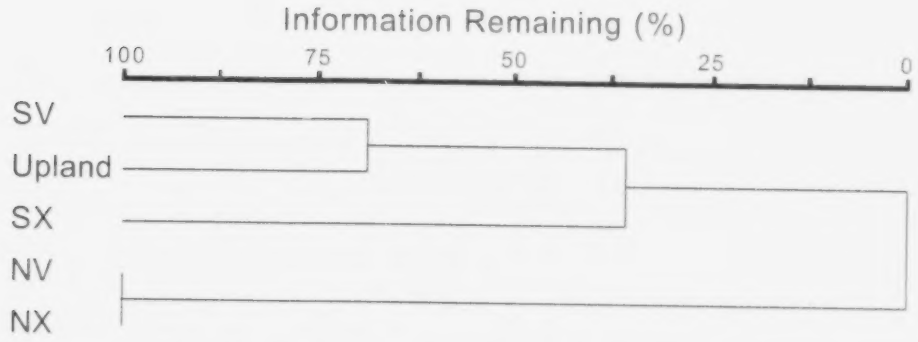

Figure 2. Cluster analysis of the plant communities in control plots in the 5 landscape elements. Abbreviations for landscape elements are SV for south aspect-concave slope, SX for south aspect-convex slope, NV for north aspect-concave slope, NX for north aspect-convex slope and Upland for level upland.

Table 2. Cover of bare soil, litter, and plant species on 5 landform elements.

	Aspect and landform element				
Cover/Species category	North aspect - Concave slope	North aspect - Convex slope	South aspect - Concave slope	South aspect - Convex slope	Level Upland
Bare soil	0	<1	<1	<1	<1
Litter	98	98	98	97	97
Graminoids					
Agropyron dasystachyum	5	7	2	3	9
Agropyron smithii	1	2	4	1	4
Agropyron subsecundum	<1	<1	<1	<1	<1
Agropyron trachycaulum	<1	<1	<1	<1	<1
Bouteloua gracilis	0	0	1	2	0
Calamagrostis montanensis	<1	<1	0	<1	<1
Carex filifolia	0	<1	<1	3	0
Carex pensylvanica	3	2	5	4	2
Carex sp.	3	3	3	6	2
Festuca hallii	20	22	10	2	5
Heirochloe odorata	<1	<1	0	0	0
Helictotrichon hookerii	<1	<1	<1	<1	<1
Juncus balticus	<1	0	<1	0	0
Koeleria cristata	<1	<1	<1	<1	<1
Muhlenbergia cuspidata	0	0	<1	<1	0
Muhlenbergia richardsonis	<1	<1	0	<1	0
Poa compressa	<1	<1	<1	0	0
Poa sp.	<1	<1	<1	<1	<1
Schizachyrium scoparium	<1	<1	0	0	0
Stipa comata	0	0	<1	1	0
Stipa curtiseta	9	5	11	13	11
Stipa viridula	0	0	<1	<1	<1
Forbs and Shrubs					
Achillea millefolium	<1	<1	<1	0	<1
Agoseris glauca	<1	<1	0	<1	<1
Anemone canadensis	<1	<1	<1	<1	<1
Anemone patens	2	2	1	1	<1
Antennaria neglecta	0	<1	0	0	0
Arabis divaricarpa	0	<1	<1	<1	<1
Artemisia frigida	2	3	1	1	1

Table 2 continued next page

Table 2 continued from previous page

Cover/Species category	Aspect and landform element: North aspect Concave slope	North aspect Convex slope	South aspect Concave slope	South aspect Convex slope	Level Upland
Artemisia ludoviciana	1	0	2	<1	<1
Aster ericoides	<1	<1	<1	<1	0
Aster falcatus	<1	<1	<1	<1	<1
Aster laevis	<1	<1	0	0	0
Astragalus flexuosus	<1	<1	<1	0	<1
Astragalus sp.	<1	<1	<1	<1	<1
Campanula rotundifolia	<1	<1	<1	<1	<1
Cerastium arvense	<1	<1	<1	<1	<1
Chenopodium album	<1	0	0	0	0
Cirsium floodmanii	0	<1	<1	0	0
Descurania sophia	0	0	<1	0	0
Erigeron caespitosus	<1	<1	<1	<1	<1
Erigeron glabellus	<1	0	<1	0	0
Erysimum inconspicuum	<1	<1	0	0	<1
Fragaria virginiana	0	<1	0	0	0
Gaillardia aristata	0	<1	0	0	0
Galium boreale	<1	<1	<1	<1	0
Geum triflorum	<1	<1	0	0	0
Grindelia squarrosa	0	0	0	<1	0
Haplopappus spinulosus	0	<1	0	0	0
Heuchera richardsonii	<1	<1	<1	0	0
Liatris punctata	0	0	<1	<1	0
Linum lewisii	0	0	<1	<1	0
Lygodesmia juncea	<1	<1	<1	<1	0
Oxytropis sericea	0	<1	0	<1	0
Penstemon procerus	0	0	<1	0	0
Petalostemon purpureum	0	0	<1	<1	0
Phlox hoodii	0	<1	<1	<1	<1
Potentilla pensylvanica	<1	<1	0	0	0
Psoralea esculenta	0	<1	<1	<1	0
Rosa arkansana	1	<1	3	3	<1
Selaginella densa	<1	<1	2	4	<1
Senecio spp.	0	<1	0	<1	0
Solidaga spp.	<1	0	0	0	0
Solidago missouriensis	<1	<1	<1	<1	0
Solidago rigida	<1	<1	0	0	0
Sonchus arvensis	0	0	<1	0	<1
Sonchus sp.	<1	0	0	0	0
Stellaria longifolia	<1	0	0	0	0
Symphoricarpos occidentalis	<1	0	0	<1	0
Taraxacum officinale	<1	<1	<1	0	0
Thermopsis rhombifolia	<1	<1	<1	<1	0
Tragopogon dubius	<1	<1	<1	<1	<1
Unknown forb	<1	0	0	0	0
Vicia americana	<1	<1	<1	<1	<1
Viola sp.	0	<1	<1	<1	0
Zizia aptera	<1	<1	0	0	0

Table 3. Percentage of current year standing crop removed by mowing in May, June, July and August on the 5 different landform elements.

Aspect and landform element	May	Jun	Jul	Aug	Average
North aspect -concave slope	76	81	81	82	80
North aspect -convex slope	74	84	77	76	78
South aspect -concave slope	80	76	80	80	79
South aspect -convex slope	74	67	72	74	72
Level Upland	75	80	79	81	79
Average	76	78	78	79	--

each of the 4-5 m sections of replicate plots. Standing crop of plants was determined in replicates 5 through 8 in June, July and August 2002 and 2003 and in June and July 2004 using the same procedures. Standing crop of species or species groups within the 4-0.25 m^2 quadrats was pooled (1 m^2) for each replicate and landform element, and current year standing crop was sorted from standing crop produced in previous years. *Festuca hallii, Stipa curtiseta* and *Agropyron dasystachyum/A. smithii* were sorted to species and species groups included forbs and shrubs and "other" graminoids (species other than *Festuca hallii, Stipa curtiseta* and *Agropyron dasystachyum/A. smithii).* Total current year standing crop, the combined weight of all species and species groups, was also calculated. Above-ground net primary production (ANPP) was determined using the incremental summation of current year standing crop technique (Redmann 1991). In this case ANPP was determined each year by summing: 1) current year standing crop in June plus positive increments in current year standing crop from: 2) June to July, and from: 3) July to August.

Soil water was determined in mid-June, mid-July and mid-August 2001, 2002 and 2003 in all replicates, landform elements and mowing treatments. Soil water was also determined in all landform elements and mowing treatments in replicates 5 through 8 in June and July 2004. Soil cores, 2.0 cm in diameter, were removed from the 0 to 30 cm depth at 2 random locations in each replicate plot, weighed, dried at 80°C for 48 hours, and weighed. Soil water was calculated on a dry weight basis. Temperature and precipitation were obtained from an official Environment Canada weather station located at Rock Point, about 10 km from the study site. Annual temperatures in 2001 to 2004 were average or 1°C above or below average (Table 4). Precipitation was 8 to 18% above the long-term average in 2 years and 27 to 45% below average in 2 years (Table 4).

Table 4. Average monthly temperatures, long-term average temperatures (1974-2004), monthly precipitation and long-term average precipitation at Rock Point, Saskatchewan. Data provided by Environment Canada upon special request.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Temperature (°C)												
2000	-15	-8	0	5	11	14	19	18	13	6	-5	-17	4
2001	-6	-15	-1	6	13	16	20	21	14	4	0	-10	5
2002	-11	-5	-13	0	9	17	20	17	12	0	-3	-5	3
2003	-13	-14	-6	5	12	16	20	22	12	9	-9	-7	4
2004	-16	-8	-1	6	8	13	18	15	12	4	-1	-9	4
Average	-14	-10	-4	5	11	16	19	18	12	5	-5	-11	4
	Precipitation (mm)												
2000	18	2	10	41	22	93	94	38	54	11	20	28	432
2001	6	10	3	4	34	29	74	1	9	8	11	10	201
2002	12	3	14	9	7	130	45	85	45	22	12	16	400
2003	21	25	3	52	24	38	33	7	33	21	6	5	268
2004	11	5	7	8	51	74	59	106	28	24	1	26	399
Average	16	10	17	22	51	69	60	36	30	19	16	20	367

Within years after mowing, months of harvest, and landform elements, data of current year standing crop and soil water were analyzed with a randomized complete block design analysis of variance with dates of mowing as the treatment effect (Petersen 1985). Current year standing crop, ANPP and soil water in unmowed controls of the 5 landform elements were compared within months of determination with analysis of variance in a randomized complete block design. The ANPP for all mowing treatments was also tested within years and landform elements with analysis of variance in a randomized complete block design. Means of current year standing crop and soil water were compared to the control with Fischer's Protected LSD

(Petersen 1985) within each landform element for each month of mowing. Fischer's Protected LSD was also used to compare standing crop, ANPP and soil water in control plots of the 5 landform elements. We considered that plants had recovered their production potential after mowing on the first month of at least 2 consecutive months in which current year standing crop was not different from the unmowed control. In all cases statistical significance was assumed at $P \leq 0.05$.

Results

Soil water

Soil water at the 0 to 30 cm depth was usually least on the south aspect-convex landform element (Table 5). Mowing on the south aspect-concave slope, south aspect-convex slope and level upland landform elements generally had no affect on soil water. Soil water on the north aspect-concave slope landform element was reduced in July of year 2 by mowing in the previous June, July, September, October or November; in August of year 2, soil water was reduced if mowed in June or April. Soil water on the north aspect-convex slope landform element was reduced in July of year 1 after mowing in May; however, soil water was greater than the control in August of year 1 if mowed in June or July. Similarly, soil water on the north aspect-convex slope landform element was greater in the August, September, October, November or April mowing than in the control in June of year 2. Soil water was similar among months of mowing on landform elements in year 3.

Above-ground net primary production

Agropyron dasystachyum/A. smithii

Above-ground net primary production (ANPP) of *Agropyron dasystachyum/A. smithii* was greatest on the level upland landform element (Table 6). Except for the south aspect-convex slope landform element, mowing in June or July reduced ANPP in year 1, but mowing had no affect on ANPP in any other year.

Festuca hallii

Festuca hallii ANPP was greatest on north aspects and least on the south aspect-convex slope landform element (Table 6). Mowing the north aspect-concave slope, north aspect-convex slope and the south aspect-concave slope landform elements reduced ANPP until year 3. By comparison, mowing on the level upland landform element in June or July reduced ANPP in year 1. Mowing had no affect on ANPP of *Festuca hallii* on the south aspect-convex slope landform element.

Stipa curtiseta

The ANPP of *Stipa curtiseta* was greatest on the south aspect-convex slope landform element and least on north aspect-concave slope and north aspect-convex slope landform elements (Table 6). Except for reduced ANPP in year 1 after mowing in May, June or July, ANPP was not affected by mowing.

Table 5. Soil water (%) at the 0 to 30 cm depth in 5 landform elements during the first 3 years after mowing.

Month and order of mowing		Year 1			Year 2			Year 3	
		Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul
		North aspect - Concave slope							
Control		23	24	15A[3]	24A	13a[3]A	14a	19A	16A
May		24	23	16	21	12a	14a	20	17
Jun.			20	17	23	11b	12b	18	15
Jul.				18	24	11b	13a	18	15
Aug.					24	13a	13a	19	15
Sep.					24	11b	12b	18	15
Oct.					24	11b	13a	20	15
Nov.					23	10b	13a	19	17
Apr.					24	12a	11b	18	15
	SE[1]	1.0	1.2	0.9	1.1	0.8	0.7	1.7	1.9
	P[4]	0.56	0.16	0.13	0.77	0.04	0.03	0.25	0.59
		North aspect - Convex slope							
Control		20	23a	14aAB	21aAB	12B	14	19AB	15A
May		20	21b	15a	20a	11	12	18	15
Jun.			22a	16b	22a	10	13	18	15
Jul.				17b	21a	13	12	18	15
Aug.					23b	11	12	18	14
Sep.					24b	10	12	18	15
Oct.					23b	11	13	17	13
Nov.					24b	12	13	18	14
Apr.					23b	13	13	18	14
	SE	1.0	0.5	0.6	0.6	0.7	0.5	1.1	1.2
	P	0.89	0.04	0.03	<0.01	0.06	0.39	0.75	0.60
		South aspect - Concave slope							
Control		21a	22	13BC	22AB	11aA	18	18AB	13AB
May		18b	20	12	22	11a	9	17	14
Jun.			21	13	23	10a	10	16	13
Jul.				13	22	8b	10	16	11
Aug.					23	10a	9	16	13
Sep.					24	11a	11	16	15
Oct.					20	10a	10	16	12
Nov.					20	11a	10	16	12
Apr.					22	9a	10	17	13
	SE	0.8	0.7	0.7	1.0	0.6	2.4	1.8	2.1
	P	0.04	0.29	0.74	0.63	0.03	0.27	0.52	0.07
		South aspect - Convex slope							
Control		17	20	11C	20B	9C	9	15C	11C
May		15	16	9	17	8	8	14	10
Jun.			18	10	19	8	7	14	10
Jul.				11	19	10	9	14	11
Aug.					18	9	8	14	10
Sep.					19	9	8	14	10
Oct.					16	8	8	14	11
Nov.					19	8	8	14	10
Apr.					19	8	9	13	10
	SE	1.0	1.7	0.4	1.0	0.7	0.4	0.8	0.3
	P	0.15	0.25	0.11	0.90	0.19	0.42	0.63	0.35

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Soil water continued from previous page

Month and order of mowing	Year 1			Year 2			Year 3	
	Jun.	Jul.	Aug.	Jun.	Jul.	Aug.	Jun.	Jul.
	Level Upland							
Control	22	20a	14AB	21AB	11B	12	16BC	13BC
May	18	17b	12	19	11	10	16	12
Jun.		20a	13	19	10	10	15	13
Jul.			15	20	10	10	15	13
Aug.				19	10	10	16	12
Sep.				19	10	10	16	13
Oct.				21	12	11	16	13
Nov.				21	10	11	17	13
Apr.				17	10	11	16	12
SE	1.4	0.8	0.7	0.9	0.6	0.5	1.1	1.2
P	0.12	0.02	0.11	0.20	0.21	0.08	0.53	0.96
$SE_{Controls}$ [5]	1.6	1.4	0.8	1.1	0.6	3.2	1.0	0.8
$P_{Controls}$ [6]	0.18	0.30	<0.01	0.05	<0.01	0.36	0.01	<0.01

[1] Means that are followed by the same lower case letter within years, months and landform elements are not significantly ($P \leq 0.05$) different from the control.

[2] Means that are followed by the same upper case letter within columns are not significantly different ($P \leq 0.05$) for controls in the 5 landform elements.

[3] SE is the standard error for the means within months, years and landform elements.

[4] P is the probability that means are significantly different within months, years and landform elements.

[5] $SE_{Controls}$ is the standard error for the means of controls within columns in the 5 landform elements.

[6] $P_{Controls}$ is the probability that means of controls within columns are significantly different among landform elements.

Table 6. Above-ground net primary production (g m^{-2}) of *Agropyron dasystachyum/A. smithii*, *Festuca hallii*, *Stipa curtiseta*, "other" graminoids, forbs and shrubs, and total in the first 3 years after mowing on 5 landform elements.

Month and order of mowing	*Agropyron dasystachyum/A. smithii*			*Festuca hallii*			*Stipa curtiseta*			Other graminoids			Forbs and shrubs			Total		
	Year			Year			Year			Year			Year			Year		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
North aspect - Concave slope																		
Control	32a[2] B[3]	15B	18BC	89aA	98aA	124A	27aB	8C	27B	19aC	8B	10B	36a	31	37	147aA	140a	185
May	29a	12	24	64b	74b	104	14b	11	15	21a	10	26	35a	26	35	126b	118b	176
Jun.	11b	16	18	32b	61b	118	8b	17	24	11a	6	13	17b	19	43	64b	107b	184
Jul.	7b	14	25	25b	71b	133	5b	11	11	3b	15	15	10b	23	30	43b	103b	188
Aug.		10	14		60b	109		9	14		11	17		32	32		95b	165
Sep.		13	26		72b	112		8	19		8	11		26	32		99b	165
Oct.		13	36		70b	118		11	17		9	13		25	34		102b	187
Nov.		13	21		88b	100		11	14		10	13		24	35		117b	161
Apr.		13	35		61b	112		6	11		5	17		39	41		103b	184
SE[1]	5.3	3.1	9.3	4.7	7.3	9.4	3.6	2.9	5.0	3.0	2.4	4.4	3.5	5.7	7.6	5.1	7.3	11.4
P[4]	<0.01	0.97	0.75	<0.01	<0.01	0.39	<0.01	0.33	0.32	<0.01	0.25	0.34	<0.01	0.42	0.96	<0.01	<0.01	0.54
North aspect - Convex slope																		
Control	32aB	18B	13C	92aA	83aAB	132A	18aC	8C	8B	22aB	5B	7B	35a	29	42	138aAB	122a	181
May	24a	10	8	66b	79a	132	23a	9	6	20a	10	7	31a	36	43	118b	110a	183
Jun.	8b	11	18	40b	64a	92	14b	8	9	10b	8	8	22b	44	58	75b	110a	165
Jul.	4b	14	15	18b	52b	107	5b	10	10	5b	11	11	11b	27	40	37b	85b	160
Aug.		19	20		54b	92		6	10		9	26		30	43		83b	167
Sep.		17	13		68a	101		7	9		5	12		29	28		113a	143
Oct.		11	9		86a	109		7	7		7	7		23	34		110a	154
Nov.		7	10		82a	114		3	8		4	12		23	46		113a	171
Apr.		11	13		54b	118		9	7		6	8		24	37		83b	163
SE	3.8	3.3	3.5	6.3	8.0	13.9	3.6	1.9	2.3	3.6	2.0	6.2	3.9	4.8	7.8	4.9	9.8	15.0
P	<0.01	0.18	0.29	<0.01	<0.01	0.36	0.02	0.38	0.96	<0.01	0.20	0.47	<0.01	0.06	0.33	<0.01	0.03	0.72
South aspect - Concave slope																		
Control	25aB	22B	29B	51aB	57aB	65B	29aB	25BC	38AB	31aB	16A	20AB	34a	30	43	135aAB	120a	159
May	26a	23	50	26b	30b	55	28a	46	45	36a	23	27	31a	20	31	111b	129a	179
Jun.	7b	18	26	10b	17b	46	16b	37	40	14b	22	24	17b	22	35	62b	110a	156
Jul.	4b	16	30	12b	27b	58	7b	30	29	8b	18	18	6b	21	28	39b	118a	144
Aug.		16	36		19b	50		26	40		24	21		18	25		102a	153
Sep.		16	27		30b	56		17	27		16	18		23	45		90b	147
Oct.		17	29		30b	43		40	40		16	19		24	24		118a	145
Nov.		20	23		35b	57		36	31		14	25		24	35		118a	158
Apr.		17	38		27b	49		25	38		18	24		23	38		100a	167
SE	3.3	3.4	6.6	2.8	5.2	7.9	3.1	6.5	6.0	3.4	2.9	4.0	3.7	3.1	7.6	4.9	8.4	8.9
P	<0.01	0.75	0.15	<0.01	<0.01	0.66	<0.01	0.07	0.40	<0.01	0.23	0.76	<0.01	0.40	0.68	<0.01	0.04	0.14

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ANPP continued from previous page

Month and order of mowing	*Agropyron dasystachyum/A. smithii*			*Festuca hallii*			*Stipa curtiseta*			Other graminoids			Forbs and shrubs			Total		
	Year			Year			Year			Year			Year			Year		
	-1-	-2-	-3-	-1-	-2-	-3-	-1-	-2-	-3-	-1-	-2-	-3-	-1-	-2-	-3-	-1-	-2-	-3-
	South aspect-Convex slope																	
Control	14B	13B	19BC	9C	5C	13C	50aA	56A	64A	40aA	24A	29A	39a	36a	37	120aB	109a	139
May	18	13	15	6	7	9	34b	38	54	38a	20	31	25a	22b	34	87b	92b	122
Jun.	3	8	11	1	4	5	25b	46	91	15b	26	24	16b	25b	35	59b	98a	139
Jul.	2	8	11	4	14	26	15b	31	37	12b	22	32	7b	26b	39	39b	81b	123
Aug.		9	19		9	15		40	76		19	22		22b	34		86b	142
Sep.		8	18		7	15		40	59		19	29		16b	40		79b	146
Oct.		8	22		10	12		46	79		21	23		17b	22		90b	140
Nov.		8	19		7	18		40	62		32	32		25b	35		92b	138
Apr.		7	15		18	22		37	65		19	21		21b	33		85b	132
SE	5.1	2.5	4.8	2.7	3.3	5.8	4.0	5.9	12.2	4.7	3.4	3.8	4.4	3.7	5.9	5.3	5.3	8.6
P	0.10	0.67	0.77	0.21	0.10	0.30	<0.01	0.18	0.15	<0.01	0.14	0.23	<0.01	0.02	0.67	<0.01	<0.01	0.50
	Level Upland																	
Control	64aA	58A	57A	32aBC	51B	47BC	34aAB	33B	58A	53aA	9B	15B	26a	18	19	125aB	124	162
May	45b	37	59	31a	67	59	34a	31	51	35b	8	22	15a	23	20	117a	136	174
Jun.	30b	42	63	19b	40	58	18b	39	52	26b	13	32	10b	15	16	73b	128	174
Jul.	14b	46	67	8b	31	45	10b	25	51	4b	7	14	4b	13	30	39b	101	168
Aug.		44	62		32	52		15	41		8	10		10	28		101	158
Sep.		41	73		31	78		19	37		9	12		18	18		97	167
Oct.		36	51		45	66		25	39		7	12		13	22		107	162
Nov.		48	81		47	51		20	41		4	16		15	18		108	177
Apr.		51	63		43	73		21	33		8	14		14	19		118	161
SE	4.7	8.0	13.0	4.1	9.0	13.1	4.7	5.9	11.8	4.5	2.1	5.5	4.2	3.9	5.2	5.2	11.0	13.4
P	<0.01	0.66	0.88	<0.01	0.14	0.61	<0.01	0.12	0.86	<0.01	0.34	0.16	0.01	0.52	0.58	<0.01	0.16	0.97
$SE_{Controls}$ [5]	6.4	6.8	5.1	8.8	13.2	17.1	6.2	6.9	12.5	6.6	2.2	4.0	6.2	5.5	6.9	6.1	13.2	16.3
$P_{Controls}$ [6]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.02	<0.01	<0.01	<0.01	0.66	0.27	0.13	0.04	0.60	0.30

[1] Means that are followed by the same lower case letter within years, months and landform elements are not significantly ($P \leq 0.05$) different from the control.
[2] Means that are followed by the same cupper case letter within columns are not significantly different ($P \leq 0.05$) for controls in the 5 landform elements.
[3] SE is the standard error for the means within species, years and landform elements.
[4] P is the probability that means are significantly different within species, years and landform elements.
[5] $SE_{Controls}$ is the standard error for the means of controls within columns in the 5 landform elements.
[6] $P_{Controls}$ is the probability that means of controls within columns are significantly different among landform elements.

Other graminoids

Other graminoids includes grasses and sedges that were not abundant enough on all landform elements to justify being treated as individual species. The ANPP of other graminoids was greatest on the level upland and south aspect-convex landform elements in year 1, but in years 2 and 3 ANPP was greatest on landform elements with southerly aspects (Table 6). Mowing in June or July reduced ANPP on all landform elements in year 1, but not in any other year.

Forbs and shrubs

The ANPP of forbs and shrubs was similar among landform elements in all 3 years (Table 6). Regardless of landform element, mowing in June or July reduced ANPP in year 1. Mowing in all months on the south aspect-convex landform element reduced ANPP in year 2.

Total standing crop

Total ANPP was greatest on the north aspect-concave slope, the north aspect-convex slope and the south aspect-concave slope landform elements in year 1, but total ANPP did not vary among landform elements in years 2 and 3 (Table 6). Except for the level upland landform element, mowing on all landform elements reduced total ANPP in year 1. Mowing had no affect on total ANPP in year 2 on the level upland landform element, however, total ANPP varied among months of mowing on the other landform elements. Total ANPP was unaffected by mowing on all landform elements in year 3.

Current year standing crop

Agropyron dasystachyum/A. smithii

Current year standing crop of *Agropyron dasystachyum/A. smithii* was always greatest on the level upland landform element, whereas it was similar among the 4 other landform elements (Table 7). *Agropyron dasystachyum/A. smithii* current year standing crop was unaffected by mowing on the north aspect-concave slope and south aspect-convex slope landform elements. Mowing in July reduced current year standing crop on the north aspect-convex slope landform element in August of year 1 while mowing in May, October or November reduced current year standing crop in August of year 2. On the south aspect-concave slope landform element, current year standing crop was reduced in July by mowing in June of that year. Mowing in May, June or July reduced current year standing crop during year 1 on the level upland landform element.

Festuca hallii

Current year standing crop of *Festuca hallii* was greatest on the north aspect-concave slope and north aspect-convex slope landform elements and least on the south aspect-convex slope landform element (Table 8). Current year standing crop was generally reduced in year 1 by mowing in June or July on north aspect-concave slope, north aspect- convex slope and south aspect-concave slope landform elements. In June of year 2, current year standing crop on the north aspect-concave slope landform element was reduced by mowing in the previous June, July, August, September, October and April. Except after mowing in June, August and September, current year standing crop was similar to control in August of year 2. Mowing in June, July, August, September or April on the north aspect-convex slope landform element

Table 7. Current year standing crop (g m^{-2}) for *Agropyron dasystachyum/A. smithii* in control and plots mowed in 5 landform elements the first 3 years after mowing.

Month and order of mowing		Year 1			Year 2			Year 3	
		---Jun.---	---Jul.---	--Aug.--	---Jun.---	---Jul.---	--Aug.--	---Jun.---	---Jul.---
		North aspect - Concave slope							
Control		25B[2]	12B	14B	9B	14B	12B	14B	12B
May		17	14	18	8	12	10	10	16
Jun.			9	9	9	21	19	9	12
Jul.				7	9	18	8	13	20
Aug.					5	9	10	8	9
Sep.					6	17	11	15	22
Oct.					7	12	6	13	25
Nov.					9	18	13	7	18
Apr.					9	12	8	7	23
	SE[3]	6.8	3.3	3.7	2.3	4.5	3.4	3.0	6.9
	P[4]	0.45	0.57	0.17	0.89	0.69	0.38	0.44	0.72
		North aspect - Convex slope							
Control		24B	16B	11a[1]B	13B	12B	16aB	8B	9B
May		16	16	9a	5	9	6b	6	7
Jun.			6	7a	5	10	8a	15	11
Jul.				4b	7	7	10a	7	12
Aug.					12	17	15a	17	14
Sep.					9	15	16a	9	8
Oct.					6	11	6b	7	6
Nov.					4	8	4b	6	6
Apr.					5	6	7a	9	9
	SE	3.6	4.2	5.1	2.4	3.4	3.0	3.1	3.1
	P	0.16	0.18	0.03	0.09	0.31	0.04	0.16	0.55
		South aspect - Concave slope							
Control		16B	20aB	13B	15B	23B	18B	16B	22B
May		18	24a	10	15	16	20	9	32
Jun.			6b	6	10	18	15	11	22
Jul.				4	12	25	12	15	22
Aug.					11	17	20	20	30
Sep.					10	18	16	18	20
Oct.					8	14	15	15	25
Nov.					15	19	15	16	23
Apr.					14	18	11	13	24
	SE	3.1	3.5	2.2	2.7	3.6	3.2	2.6	4.8
	P	0.74	<0.01	0.06	0.48	0.53	0.56	0.17	0.74
		South aspect - Convex slope							
Control		12B	8B	5B	8B	10B	9B	11B	16B
May		13	8	12	11	10	10	7	9
Jun.			2	3	4	5	6	7	10
Jul.				2	6	9	4	9	7
Aug.					5	9	10	7	15
Sep.					5	5	5	6	13
Oct.					4	6	9	10	18
Nov.					4	9	7	9	13
Apr.					5	8	7	7	11
	SE	4.1	3.4	4.9	1.9	3.0	3.4	2.4	3.6
	P	0.92	0.43	0.45	0.14	0.84	0.90	0.91	0.56

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Month and order of mowing	Year 1			Year 2			Year 3	
	Jun.	Jul.	Aug.	Jun.	Jul.	Aug.	Jun.	Jul.
	Level Upland							
Control	59aA	49aA	37aA	51A	39A	34A	36A	49A
May	24b	32b	21b	30	23	27	38	46
Jun.		24b	26b	40	53	36	28	44
Jul.			14b	40	42	46	55	45
Aug.				33	37	37	34	46
Sep.				30	36	30	38	53
Oct.				20	31	34	26	36
Nov.				35	44	34	38	61
Apr.				34	44	37	31	50
SE	4.6	3.6	3.6	7.2	7.5	7.0	8.5	9.4
P	<0.01	<0.01	<0.01	0.21	0.26	0.76	0.45	0.81
$SE_{Controls}$ [5]	4.9	6.1	4.2	6.8	5.4	5.1	5.7	4.5
$P_{Controls}$ [6]	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01	<0.01

[1] Means that are followed by the same lower case letter within years, months and landform elements are not significantly ($P \leq 0.05$) different from the control.

[2] Means that are followed by the same upper case letter within columns are not significantly different ($P \leq 0.05$) for controls in the 5 landform elements.

[3] SE is the standard error for the means within species, years and landform elements.

[4] P is the probability that means are significantly different within species, years and landform elements.

[5] $SE_{Controls}$ is the standard error for the means of controls within columns in the 5 landform elements.

[6] $P_{Controls}$ is the probability that means of controls within columns are significantly different among landform elements.

Table 8. Current year standing crop (g m^{-2}) for *Festuca hallii* in control and plots mowed in 5 landform elements the first 3 years after mowing.

Month and order of mowing		Year 1			Year 2			Year 3	
		---Jun.---	---Jul.---	--Aug.–	---Jun.---	---Jul.---	--Aug.–	---Jun.---	---Jul.---
		North aspect - Concave slope							
Control		63A[2]	66a[1]A	70aA	74aAB	78AB	88aA	91A	115A
May		56	55a	45b	66a	89	63a	84	94
Jun.			23b	31b	53b	69	52b	89	96
Jul.				25b	49b	66	67a	87	118
Aug.					49b	67	47b	77	103
Sep.					50b	61	58b	66	96
Oct.					58b	83	71a	80	113
Nov.					61a	77	83a	86	96
Apr.					43b	73	78a	80	106
	SE[3]	5.7	5.9	3.4	5.2	7.3	9.0	7.6	9.6
	P[4]	0.37	<0.01	<0.01	<0.01	0.18	0.03	0.41	0.47
		North aspect - Convex slope							
Control		63A	78aA	60aA	79aA	88A	66aAB	79A	114A
May		50	45b	46a	59a	74	66a	69	118
Jun.			21b	36b	53b	64	56a	71	87
Jul.				18b	43b	66	54a	78	90
Aug.					41b	57	48b	65	87
Sep.					58b	58	54a	65	96
Oct.					68a	68	73a	74	109
Nov.					61a	78	80a	87	106
Apr.					43b	72	62a	64	105
	SE	5.6	6.7	5.8	7.2	7.3	6.3	6.7	10.0
	P	0.15	<0.01	<0.01	<0.01	0.08	0.01	0.25	0.23
		South aspect - Concave slope							
Control		30B	39aB	35aB	42aBC	54aABC	36aBC	42B	60B
May		16	13b	19b	21b	29b	22b	36	41
Jun.			9b	8b	11b	19b	13b	32	41
Jul.				12b	20b	28b	21b	48	53
Aug.					17b	20b	16b	30	46
Sep.					23b	31b	25a	38	53
Oct.					18b	24b	22b	37	37
Nov.					21b	39a	27a	45	47
Apr.					21b	27b	23b	36	46
	SE	4.4	5.9	4.3	4.6	6.8	4.1	6.2	7.6
	P	0.06	<0.01	<0.01	<0.01	0.02	0.02	0.51	0.51
		South aspect - Convex slope							
Control		7C	8C	3C	2D	7aC	4aC	6C	11C
May		1	1	5	6	4a	1a	4	6
Jun.			1	1	3	2a	1a	5	1
Jul.				4	7	12a	15b	20	20
Aug.					5	8a	7a	15	9
Sep.					3	5a	7a	15	12
Oct.					7	5a	6a	11	10
Nov.					4	2a	5a	6	9
Apr.					10	18b	17b	17	19
	SE	4.3	2.6	1.8	2.7	3.1	3.3	5.3	5.4
	P	0.36	0.11	0.52	0.54	<0.01	0.01	0.25	0.27

Table continued next page

Festuca hallii continued from previous page

Month and order of mowing	Year 1			Year 2			Year 3	
	---Jun.---	---Jul.---	--Aug.--	---Jun---	---Jul---	--Aug--	---Jun---	---Jul---
	Level Upland							
Control	15BC	20BC	21BC	18CD	40BC	50B	20BC	39BC
May	21	24	19	44	33	48	32	51
Jun.		10	15	27	19	31	30	36
Jul.			8	28	26	19	21	38
Aug.				24	25	27	28	46
Sep.				23	35	34	45	50
Oct.				38	47	39	3	63
Nov.				29	25	36	38	44
Apr.				28	32	42	56	58
SE	3.4	4.9	3.8	7.1	8.1	9.6	9.4	10.1
P	0.27	0.14	0.10	0.24	0.35	0.38	0.15	0.60
$SE_{Controls}$[5]	6.8	9.1	8.2	11.7	12.9	11.2	10.0	14.1
$P_{Control}$[6]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[1] Means that are followed by the same lower case letter within years, months and landform elements are not significantly ($P \leq 0.05$) different from the control.

[2] Means that are followed by the same upper case letter within columns are not significantly different ($P \leq 0.05$) for controls in the 5 landform elements.

[3] SE is the standard error for the means within species, years and landform elements.

[4] P is the probability that means are significantly different within species, years and landform elements.

[5] $SE_{Controls}$ is the standard error for the means of controls within columns in the 5 landform elements.

[6] $P_{Controls}$ is the probability that means of controls within columns are significantly different among landform elements.

reduced current year standing crop in June of year 2. Mowing south aspect-concave slope and level upland landform elements had no affect on current year standing crop.

Stipa curtiseta

Current year standing crop of *Stipa curtiseta* was generally greatest on south aspect-concave slope, south aspect-convex slope and level upland landform elements and least on the north aspect-concave slope and north aspect-convex slope landform elements (Table 9). Mowing had no effect on current year standing crop on the north aspect-concave slope landform element. Mowing the north aspect-concave slope landform element in July reduced standing crop in year 1 while mowing in November reduced current year standing crop in year 2. Current year standing crop was reduced in year 1 by mowing the south aspect-concave slope landform element in June or July. Mowing on the south aspect-convex slope landform element reduced current year standing crop in July and August of Year 1; July and August mowing reduced current year standing crop in August of year 2. Current year standing crop on the level upland landform element was reduced the month after mowing in June or July of year 1 whereas August, September and April mowing reduced standing crop in August of year 2.

Other graminoids

Current year standing crop of other graminoids was greatest on the south aspect-convex slope landform element (Table 10). Mowing in June or July reduced current year standing crop in year 1 on the north aspect-concave slope landform element. July mowing on the south aspect-convex slope landform element in July reduced current year standing crop the next month; mowing in August or September reduced current year standing crop in August of year 2. July mowing on the level upland landform element reduced current year standing crop in August of year 1. Current year standing crop was unaffected by mowing on the north aspect-convex slope and south aspect-concave slope landform elements.

Forbs and shrubs

With the exception of the less current year standing crop on the level upland landform element in June of year 1 and July of year 2, current year standing crop of forbs and shrubs was similar among landform elements (Table 11). Except for the south aspect-convex slope landform element, current year standing crop was unaffected or reduced by mowing only in year 1. Current year standing crop of forbs and shrubs was unaffected by mowing level uplands and north aspect-convex slope landform elements. Mowing in June reduced current year standing crop of forbs and shrubs in July of year 1 on the north aspect-concave slope landform element. Mowing in June or July reduced current year standing crop of forbs and shrubs on the south aspect-concave slope landform element in year 1. Current year standing crop was reduced by May, June and July mowing in year 1 on the south aspect-convex slope landform element; mowing in August, September, October, November or April reduced current year standing crop in June of year 2.

Total standing crop

Except for June and July of year 1 and June of year 3 when current year total standing crop was greatest on north aspects, current year total standing crop was similar ($P \leq 0.05$) among landform elements (Table 12). Current year total standing crop on the north aspect-concave slope landform element was reduced in year 1 by mowing in May, June or July.

Table 9. Current year standing crop (g m^{-2}) for *Stipa curtiseta* in control and plots mowed in 5 landform elements the first 3 years after mowing.

Month and order of mowing		Year 1			Year 2			Year 3	
		---Jun.---	---Jul---	--Aug --	---Jun.---	---Jul---	--Aug --	---Jun.---	---Jul---
		North aspect -concave slope							
Control		10B[1]	20BC	11B	5B	13B	14C	3B	16C
May		6	9	11	8	14	10	4	11
Jun.			6	7	7	16	12	16	21
Jul.				5	5	14	8	9	7
Aug.					4	5	6	7	13
Sep.					4	9	10	11	12
Oct.					5	6	9	9	13
Nov.					3	9	4	14	9
Apr.					3	5	6	3	8
	SE[3]	1.6	3.8	2.6	1.9	3.2	2.8	3.7	4.2
	P[4]	0.14	0.06	0.28	0.53	0.12	0.36	0.18	0.39
		North aspect -convex slope							
Control		3B	11C	12a[1]B	3B	9B	7aC	3B	5C
May		5	11	19a	5	11	7a	4	4
Jun.			7	11a	4	10	10a	4	6
Jul.				5b	5	10	7a	6	6
Aug.					4	5	5a	4	8
Sep.					3	6	7a	6	5
Oct.					2	5	3a	6	7
Nov.					2	5	2b	5	5
Apr.					3	10	5a	5	5
	SE	0.9	3.4	3.1	0.9	2.3	1.3	1.4	1.7
	P	0.39	0.72	0.04	0.12	0.27	0.01	0.71	0.88
		South aspect -concave slope							
Control		24A	22aABC	22aB	16B	31A	23BC	17AB	24aBC
May		21	25a	19a	31	28	38	24	39b
Jun.			9b	16a	31	30	32	17	29a
Jul.				6b	22	17	25	13	20a
Aug.					22	23	18	15	29a
Sep.					13	18	20	12	17a
Oct.					32	33	32	15	29a
Nov.					27	22	25	16	26a
Apr.					23	29	21	12	26a
	SE	3.9	2.9	3.2	5.5	4.6	4.5	3.4	4.3
	P	0.65	<0.01	0.01	0.17	0.16	0.06	0.30	0.04
		South aspect -convex slope							
Control		26A	38aA	39aA	47A	55AB	43aA	32aA	55A
May		22	29a	27b	31	41	36a	39a	44
Jun.			16b	24b	31	45	46a	47b	72
Jul.				15b	22	32	23b	23a	34
Aug.					35	41	28b	25a	58
Sep.					32	28	42a	29a	51
Oct.					38	52	40a	36a	69
Nov.					30	27	31a	33a	45
Apr.					30	36	37a	25a	51
	SE	5.3	5.1	3.9	3.1	7.0	5.1	5.2	9.3
	P	0.64	0.03	<0.01	0.30	0.34	0.03	0.04	0.14

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Month and order of mowing	Year 1			Year 2			Year 3	
	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul
	Level Upland							
Control	16AB	31aAB	23aB	15B	37AB	31aAB	17AB	45AB
May	26	29a	28a	15	43	34a	28	47
Jun.		11b	16a	26	38	28a	27	45
Jul.			10b	8	31	24a	20	40
Aug.				12	19	9b	15	32
Sep.				8	15	15b	16	31
Oct.				12	15	26a	15	33
Nov.				13	24	19a	13	31
Apr.				9	20	17b	12	23
SE[3]	3.3	5.2	3.9	4.7	7.5	4.5	5.7	10.0
P[4]	0.06	0.03	0.02	0.22	0.07	<0.01	0.41	0.71
$SE_{Controls}$[5]	4.6	6.3	5.3	7.0	10.0	5.5	5.2	9.7
$P_{Controls}$[6]	0.01	0.04	<0.01	<0.01	0.02	<0.01	<0.01	<0.01

[1] Means that are followed by the same lower case letter within years, months and landform elements are not significantly ($P \geq 0.05$) different from the control.

[2] Means that are followed by the same upper case letter within columns are not significantly different ($P \geq 0.05$) for controls in the 5 landform elements.

[3] SE is the standard error for the means within species, years and landform elements.

[4] P is the probability that means are significantly different within species, years and landform elements.

[5] $SE_{Controls}$ is the standard error for the means of controls within columns in the 5 landform elements.

[6] $P_{Controls}$ is the probability that means of controls within columns are significantly different among landform elements.

Table 10. Current year standing crop (g m^{-2}) for graminoids (excluding *Agropyron dasystachyum/A. smithii*, *Festuca hallii* and *Stipa curtiseta*) in control and plots mowed in 5 landform elements the first 3 years after mowing.

Month and order of mowing		Year 1			Year 2			Year 3	
		Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul
		North aspect - Concave slope							
Control		7B[3]	5b[3]C	12aB	4B	6C	5CD	5C	8BC
May		5	13a	10a	4	11	12	8	16
Jun.			4b	5b	5	6	4	8	9
Jul.				3b	5	5	14	7	10
Aug.					5	4	10	11	12
Sep.					3	5	7	8	5
Oct.					3	8	8	8	8
Nov.					4	6	8	8	12
Apr.					3	8	7	6	10
	SE[1]	2.0	2.6	2.3	1.4	2.2	2.7	2.2	3.6
	P[4]	0.51	0.03	0.04	0.89	0.57	0.48	0.68	0.64
		North aspect - Convex slope							
Control		6B	6C	7B	3B	3C	3D	3C	5C
May		6	6	7	5	7	7	5	5
Jun.			2	7	6	5	6	6	6
Jul.				5	4	8	11	6	7
Aug.					6	6	4	4	16
Sep.					3	4	5	5	7
Oct.					2	7	4	6	5
Nov.					3	5	5	7	5
Apr.					4	6	5	7	5
	SE	1.9	1.3	1.1	1.6	1.6	2.1	1.8	3.1
	P	0.83	0.10	0.27	0.48	0.63	0.44	0.81	0.22
		South aspect - Concave slope							
Control		17A	13B	13AB	12aA	20B	12B	14B	18AB
May		17	21	17	17a	21	19	23	16
Jun.			11	13	20b	24	15	18	19
Jul.				8	12a	16	18	11	15
Aug.					14a	16	17	16	17
Sep.					11a	17	11	16	16
Oct.					11a	22	15	12	17
Nov.					7a	12	15	16	22
Apr.					11a	19	13	14	18
	SE	2.6	2.9	2.6	2.4	3.0	2.2	4.0	2.5
	P	0.88	0.06	0.14	<0.01	0.19	0.18	0.47	0.71
		South aspect - Convex slope							
Control		23A	24aA	24aA	15A	30A	22aA	21A	23A
May		14	23a	27a	16	31	25a	23	29
Jun.			12b	15a	22	25	22a	19	23
Jul.				12b	16	21	18a	17	25
Aug.					13	24	15b	15	19
Sep.					15	21	15b	19	22
Oct.					19	18	16a	17	16
Nov.					18	23	25a	23	28
Apr.					15	25	19a	19	18
	SE	3.7	2.6	3.0	3.1	3.8	2.8	2.6	3.0
	P	0.12	<0.01	<0.01	0.71	0.27	0.05	0.39	0.05

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Other graminoids continued from previous page

Month and order of mowing	Year 1			Year 2			Year 3	
	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul
	Level Upland							
Control	4B	6aC	7aB	4aB	7C	10BC	12B	9BC
May	7	9a	10a	5a	10	7	11	13
Jun.		4a	6a	10b	7	7	7	19
Jul.			4b	5a	7	4	8	10
Aug.				3a	10	7	7	7
Sep.				3a	7	7	9	7
Oct.				4a	5	5	6	9
Nov.				2a	5	3	12	8
Apr.				3a	7	6	4	10
SE	1.8	1.4	1.5	1.5	2.1	2.1	3.0	3.7
P	0.25	0.09	0.04	0.02	0.65	0.56	0.60	0.32
$SE_{Controls}$ [5]	3.0	2.1	3.7	1.7	2.9	2.2	2.2	3.5
$P_{Controls}$ [6]	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01

[1] Means that are followed by the same lower case letter within years, months and landform elements are not significantly ($P \leq 0.05$) different from the control.

[2] Means that are followed by the same upper case letter within columns are not significantly different ($P \leq 0.05$) for controls in the 5 landform elements.

[3] SE is the standard error for the means within species, years and landform elements.

[4] P is the probability that means are significantly different within species, years and landform elements.

[5] $SE_{Controls}$ is the standard error for the means of controls within columns in the 5 landform elements.

[6] $P_{Controls}$ is the probability that means of controls within columns are significantly different among landform elements.

Table 11. Current year standing crop (g m^{-2}) for forbs and shrubs in control and plots mowed in 5 landform elements the first 3 years after mowing.

Month and order of mowing		Year 1			Year 2			Year 3	
		---Jun---	---Jul---	--Aug--	---Jun---	---Jul---	--Aug--	---Jun---	---Jul---
		North aspect - Concave slope							
Control		28A[2]	26a[1]	17a	21	30A	18	18	26
May		23	30a	28a	16	28	24	29	30
Jun.			12b	14a	11	26	16	23	32
Jul.				10b	18	24	11	22	24
Aug.					13	27	25	23	29
Sep.					16	25	16	24	22
Oct.					15	28	13	21	21
Nov.					13	28	15	16	24
Apr.					13	34	33	34	36
	SE[3]	4.0	4.8	3.9	3.2	5.3	6.0	5.3	6.6
	P[4]	0.45	0.05	0.02	0.47	0.95	0.25	0.45	0.80
		North aspect - Convex slope							
Control		18aAB	24	23	22	22AB	19	27	28
May		27b	20	17	28	25	20	28	33
Jun.			16	21	35	32	20	26	43
Jul.				11	19	23	19	17	32
Aug.					19	25	24	21	31
Sep.					24	21	15	21	24
Oct.					17	25	15	20	28
Nov.					20	23	16	26	28
Apr.					18	23	18	23	30
	SE	2.4	2.9	3.9	4.4	3.6	2.9	4.7	4.4
	P	0.03	0.23	0.14	0.09	0.64	0.50	0.74	0.23
		South aspect - Concave slope							
Control		27A	24	26a	19	28A	22	21	31
May		19	25	22a	17	29	23	19	26
Jun.			14	15b	18	26	23	20	31
Jul.				6b	16	26	19	14	25
Aug.					11	18	17	15	23
Sep.					14	28	21	17	37
Oct.					17	19	22	20	30
Nov.					17	27	21	20	27
Apr.					12	17	21	21	36
	SE	3.3	3.2	3.2	2.5	3.7	3.2	3.9	5.3
	P	0.15	0.06	<0.01	0.33	0.14	0.94	0.90	0.64
		South aspect - Convex slope							
Control		31aA	24a	21a	24a	30A	26	26	29
May		13b	13b	20a	18a	21	15	24	27
Jun.			11b	16a	22a	22	21	22	27
Jul.				7b	17a	23	20	20	34
Aug.					13b	21	16	26	28
Sep.					11b	23	16	18	32
Oct.					12b	19	18	18	21
Nov.					13b	26	21	25	30
Apr.					14b	20	14	23	24
	SE	3.3	3.4	3.2	2.9	3.3	3.1	4.3	4.8
	P	<0.01	0.03	0.02	0.04	0.40	0.24	0.83	0.67

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Forbs and shrubs continued from previous page

Month and order of mowing	Year 1			Year 2			Year 3	
	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul
	Level Upland							
Control	12B	11	17	14	11B	6	12	11
May	7	12	8	15	12	9	19	13
Jun.		5	8	6	12	7	10	9
Jul.			4	9	14	7	14	14
Aug.				6	13	6	14	14
Sep.				9	13	11	13	9
Oct.				8	15	5	13	10
Nov.				10	12	7	12	12
Apr.				7	10	6a	19	10
SE	2.8	3.2	3.5	3.3	2.5	2.0	4.2	3.2
P	0.25	0.27	0.09	0.44	0.95	0.50	0.88	0.95
$SE_{Controls}$ [5]	4.7	6.0	5.2	4.5	4.4	5.4	4.9	5.0
$P_{Controls}$ [6]	0.04	0.46	0.63	0.59	0.02	0.13	0.24	0.07

[1] Means that are followed by the same lower case letter within years, months and landform elements are not significantly ($P \leq 0.05$) different from the control.

[2] Means that are followed by the same upper case letter within columns are not significantly different ($P \leq 0.05$) for controls in the 5 landform elements.

[3] SE is the standard error for the means within species, years and landform elements.

[4] P is the probability that means are significantly different within species, years and landform elements.

[5] $SE_{Controls}$ is the standard error for the means of controls within columns in the 5 landform elements.

[6] $P_{Controls}$ is the probability that means of controls within columns are significantly different among landform elements.

Table 12. Total current year standing crop (g m^{-2}) in control and plots mowed in 5 landform elements the first 3 years after mowing.

Month and order of mowing		Year 1			Year 2			Year 3	
		---Jun.---	---Jul---	--Aug.–	---Jun.---	---Jul.---	--Aug.–	---Jun.---	---Jul.---
		North aspect - concave slope							
Control		130a[1]A[2]	130aA	115a	111a	141a	138	131A	178
May		107b	124a	99b	100a	155a	132	135	167
Jun.			55b	58b	85b	138a	105	145	170
Jul.				43b	84b	128a	122	127	180
Aug.					74b	113b	110	126	165
Sep.					76b	117b	116	124	158
Oct.					86b	138a	122	131	181
Nov.					88b	137a	123	131	158
Apr.					69b	133a	133	130	183
	SE[3]	6.0	5.9	4.4	5.4	6.6	7.7	9.2	11.6
	P[4]	0.03	<0.01	<0.01	<0.01	<0.01	0.08	0.89	0.70
		North aspect - convex slope							
Control		115AB	137aA	96a	116a	133	124	121A	160
May		104	100b	92a	98a	121	120	112	168
Jun.			53b	71b	100a	117	100	122	153
Jul.				37b	75b	100	113	113	148
Aug.					77b	104	109	112	156
Sep.					94a	108	96	106	141
Oct.					92b	116	115	113	154
Nov.					89b	109	123	132	150
Apr.					70b	111	111	107	154
	SE	3.7	3.9	5.7	7.9	7.7	7.1	6.4	9.5
	P	0.07	<0.01	<0.01	<0.01	0.14	0.80	0.16	0.76
		South aspect - concave slope							
Control		111aAB	116aAB	100a	101a	157a	110a	110AB	154
May		89b	108a	80b	98a	130b	122a	111	154
Jun.			50b	58b	86a	121b	94a	97	143
Jul.				39b	78b	125b	97a	101	136
Aug.					72b	100b	87b	95	145
Sep.					66b	109b	95a	98	142
Oct.					81b	112b	106a	98	137
Nov.					82b	129b	104a	114	145
Apr.					78b	116b	92b	97	149
	SE	6.1	7.3	5.7	6.6	7.2	6.3	6.5	7.4
	P	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	0.31	0.61
		South aspect - convex slope							
Control		93aB	97aB	98a	88a	132a	104a	96B	134
May		62b	74b	84a	78a	107b	87b	97	116
Jun.			42b	58b	75b	99b	96a	99	132
Jul.				39b	64b	98b	79b	89	120
Aug.					69b	103b	76b	88	127
Sep.					62b	92b	85b	88	130
Oct.					78a	101b	90b	93	134
Nov.					67b	98b	88b	95	125
Apr.					71b	107b	95a	91	123
	SE	6.3	6.6	6.5	4.5	5.0	4.2	4.9	7.8
	P	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.64	0.75

Table continued next page

Total current year standing crop continued from previous page

Month and order of mowing	Year 1			Year 2			Year 3	
	---Jun.---	---Jul.---	--Aug.–	---Jun.---	---Jul.---	--Aug.–	---Jun.---	---Jul.---
	Level Upland							
Control	105B	121aAB	98a	96a	133	130	97B	153
May	96	106b	92a	107a	122	125	128	170
Jun.		54b	70b	108a	130	110	102	153
Jul.			39b	85a	120	99	118	147
Aug.				74b	104	85	98	144
Sep.				71b	106	96	120	149
Oct.				80a	114	108	102	151
Nov.				85a	111	99	113	156
Apr.				78a	113	108	122	151
SE	7.2	5.0	5.8	6.7	7.1	10.2	10.1	11.1
P	0.42	<0.01	<0.01	<0.01	0.06	0.08	0.26	0.90
$SE_{Controls}$ [5]	7.7	8.4	9.4	9.2	10.7	13.3	7.2	11.4
$P_{Controls}$ [6]	0.03	0.02	0.61	0.23	0.44	0.38	<0.01	0.13

[1] Means that are followed by the same lower case letter within years, months and landform elements are not significantly ($P \leq 0.05$) different from the control.

[2] Means that are followed by the same upper case letter within columns are not significantly different ($P \leq 0.05$) for controls in the 5 landform elements.

[3] SE is the standard error for the means within species, years and landform elements.

[4] P is the probability that means are significantly different within species, years and landform elements.

[5] $SE_{Controls}$ is the standard error for the means of controls within columns in the 5 landform elements.

[6] $P_{Controls}$ is the probability that means of controls within columns are significantly different among landform elements.

Mowing in June or July reduced current year total standing crop until June of year 2 while mowing in August or September reduced total standing crop in June and July of year 2. Current year total standing crop was reduced until July of year 2 when mowed in October, November or April. Mowing the north aspect-convex slope landform element in May or June reduced current year total standing crop in year 1. The July mowing reduced current year total standing crop in August of Year 1 and June of year 2. August, October, November and April mowing reduced current year total standing crop in June of year 2, but mowing in September had no effect on current year total standing crop. Mowing in all months reduced current year total standing crop on the south aspect-concave slope and south aspect-convex slope landform elements. Current year total standing crop on the south aspect-concave slope and south aspect-convex slope landform elements was similar among mowing treatments in year 3. May, June and July mowing on the level upland landform element reduced current year total standing crop in year 1 whereas mowing in August or September reduced current year total standing crop in June of year 2.

The number of months required to restore current year standing crop after mowing

Agropyron dasystachyum/A. smithii

The number of months between mowing and the first of at least 2 consecutive months in which current year standing crop of *Agropyron dasystachyum/A. smithii* was not different from the unmowed control ranged from 1 to 13 (Table 13). Except for the level upland landform element, current year standing crop after mowing in April, May, June or July was similar to the unmowed control in the same year or growing season in which the mowing was done. Current year standing crop on the level upland landform element mowed in April was similar to the control in the first June after mowing; however, current year standing crop was similar to the unmowed control in June of the following growing season when mowed in May through November. Current year standing crop was similar to the control in June of the year after mowing in August, September, October or November on all landform elements.

Festuca hallii

One to 25 months elapsed between mowing and the first of at least 2 consecutive months in which current year standing crop of *Festuca hallii* was not different from the unmowed control (Table 13). Except for the south aspect-concave slope landform element, current year standing crop was similar to the unmowed control in the same year after mowing in April or May. The longest time for current year standing crop to recover was observed on the north aspect-concave slope, the north aspect-convex slope and the south aspect-concave slope landform elements where current year standing crop was not similar to the unmowed control until June of the second full growing season.

Stipa curtiseta

The duration between mowing and the first of at least 2 consecutive months in which current year standing crop of *Stipa curtiseta* was not different from the unmowed control varied between 1 and 12 months (Table 13). Current year standing crop after mowing in April, May and June was usually similar to the unmowed control in the same year as mowing. Current year standing crop was generally similar to that in the unmowed control in June of the following year when mowed in July through November.

Table 13. The number of months elapsed between the month of mowing and the first month of at least 2 consecutive months in which current year standing crop of *Agropyron dasystachyum A. smithii*, *Festuca hallii*, *Stipa curtiseta*, "other " graminoids, forbs and shrubs and total standing crop was not different ($P \leq 0.05$) from the unmowed control on 5 landform elements.

Month of mowing	North aspect - Concave slope	North aspect - Convex slope	South aspect - Concave slope	South aspect - Convex slope	Level Upland
			Agropyron dasystachyum/A. smithii		
Apr.	2[1]	2	2	2	2
May	1	1	1	1	13
Jun.	1	1	2	1	12
Jul.	1	11	1	1	11
Aug.	10[2]	10	10	10	10
Sep.	9	9	9	9	9
Oct.	8	8	8	8	8
Nov.	7	7	7	7	7
			Festuca hallii		
Apr.	3	3	14	2	2
May	1	3	**25**	1	1
Jun.	**24**[3]	13	**24**	1	12
Jul.	12	12	**23**	1	11
Aug.	**22**	**22**	**22**	10	10
Sep.	**21**	11	11	9	9
Oct.	9	8	**20**	8	8
Nov.	8	7	8	7	7
			Stipa curtiseta		
Apr.	2	2	2	2	2
May	1	1	1	1	1
Jun.	1	1	2	12	2
Jul.	1	11	11	11	11
Aug.	10	10	10	10	10
Sep.	9	9	9	9	9
Oct.	8	8	8	8	8
Nov.	7	7	7	7	7
			Other graminoids		
Apr.	2	2	2	2	2
May	1	1	1	1	3
Jun.	12	1	1	1	2
Jul.	11	1	1	11	11
Aug.	10	10	10	10	10
Sep.	9	9	9	9	9
Oct.	8	8	8	8	8
Nov.	7	7	7	7	7
			Forbs and shrubs		
Apr.	2	2	2	3	2
May	1	1	1	3	1
Jun.	2	1	12	2	1
Jul.	11	1	11	11	1
Aug.	10	10	10	11	10
Sep.	9	9	9	10	9
Oct.	8	8	8	9	8
Nov.	7	7	7	8	7
			Total		
Apr.	3	3	14	4	3
May	13	3	15	25	3
Jun.	13	12	14	14	12
Jul.	12	12	13	**23**	11
Aug.	12	11	**22**	**22**	11
Sep.	11	9	11	**21**	10
Oct.	9	9	10	**20**	9
Nov.	8	8	9	19	8

[1] The light gray pattern indicates current year standing crop after mowing was similar ($P \leq 0.05$) to the unmowed control in the same year or growing season in which mowing occurred.

[2] The clear or white pattern indicates current year standing crop after mowing was similar ($P \leq 0.05$) to the unmowed control in the first year or first full growing season after mowing.

[3] The dark gray pattern indicates current year standing crop after mowing was similar ($P \leq 0.05$) to the unmowed control in the second full year or second full growing season growing season after mowing.

Table 13. The number of months elapsed between the month of mowing and the first month of at least 2 consecutive months in which current year standing crop of *Agropyron dasystachyum/ A. smithii*, *Festuca hallii*, *Stipa curtiseta*, "other " graminoids, forbs and shrubs and total standing crop was not different ($P \leq 0.05$) from the unmowed control on 5 landform elements.

Month of mowing	North aspect - Concave slope	North aspect - Convex slope	South aspect - Concave slope	South aspect - Convex slope	Level Upland
			Agropyron dasystachyum/A. smithii		
Apr.	2[1]	2	2	2	2
May	1	1	1	1	13
Jun.	1	1	2	1	12
Jul.	1	11	1	1	11
Aug.	10[2]	10	10	10	10
Sep.	9	9	9	9	9
Oct.	8	8	8	8	8
Nov.	7	7	7	7	7
			Festuca hallii		
Apr.	3	3	14	2	2
May	1	3	25	1	1
Jun.	24[3]	13	24	1	12
Jul.	12	12	23	1	11
Aug.	22	22	22	10	10
Sep.	21	11	11	9	9
Oct.	9	8	20	8	8
Nov.	8	7	8	7	7
			Stipa curtiseta		
Apr.	2	2	2	2	2
May	1	1	1	1	1
Jun.	1	1	2	12	2
Jul.	1	11	11	11	11
Aug.	10	10	10	10	10
Sep.	9	9	9	9	9
Oct.	8	8	8	8	8
Nov.	7	7	7	7	7
			Other graminoids		
Apr.	2	2	2	2	2
May	1	1	1	1	3
Jun.	12	1	1	1	2
Jul.	11	1	1	11	11
Aug.	10	10	10	10	10
Sep.	9	9	9	9	9
Oct.	8	8	8	8	8
Nov.	7	7	7	7	7
			Forbs and shrubs		
Apr.	2	2	2	3	2
May	1	1	1	3	1
Jun.	2	1	12	2	1
Jul.	11	1	11	11	1
Aug.	10	10	10	11	10
Sep.	9	9	9	10	9
Oct.	8	8	8	9	8
Nov.	7	7	7	8	7
			Total		
Apr.	3	3	14	4	3
May	13	3	15	25	3
Jun.	13	12	14	14	12
Jul.	12	12	13	23	11
Aug.	12	11	22	22	11
Sep.	11	9	11	21	10
Oct.	9	9	10	20	9
Nov.	8	8	9	19	8

[1] The light gray pattern indicates current year standing crop after mowing was similar ($P \leq 0.05$) to the unmowed control in the same year or growing season in which mowing occurred.

[2] The clear or white pattern indicates current year standing crop after mowing was similar ($P \leq 0.05$) to the unmowed control in the first year or first full growing season after mowing.

[3] The dark gray pattern indicates current year standing crop after mowing was similar ($P < 0.05$) to the unmowed control in the second full year or second full growing season growing season after mowing.

Other graminoids

Twelve months or less elapsed between mowing and the first of at least 2 consecutive months in which current year standing crop of other graminoids was not different from the unmowed control (Table 13). Current year standing crop after mowing in April or May was similar to the unmowed control in June of the same year on all landform elements. Except for the north aspect-concave slope landform element, current year standing crop was similar to the unmowed control by July or August when mowed in June. Current year standing crop was generally similar to the unmowed control in June of the following year if mowed in July, August, September, October or November.

Forbs and shrubs

One to 12 months passed between mowing and the first of at least 2 consecutive months in which current year standing crop of forbs and shrubs was not different from the unmowed control (Table 13). Current year standing crop was generally similar to the control in the same year when mowed in April, May or June. Current year standing crop was similar to the unmowed control in June or July of the year following mowing in July, August, September, October or November.

Total standing crop

Up to 25 months elapsed between mowing and the first of at least 2 consecutive months in which total current year standing crop was not different from the unmowed control (Table 13). Except for the April mowing on the north aspect-concave slope landform element and the April and May mowing on the north aspect-convex and level upland landform elements, total current year standing crop was similar to the control in June through August the year after mowing. Total current year standing crop was similar to the control in June or August of the second year on the south aspect-concave slope landform element, but total current year standing crop on the south aspect-convex slope landform element was reduced until June or August of the second year.

Management Implications

This research was designed to determine the amount of time required by native range plants to regain their forage production potential after a single mowing at different times of the year on 5 easily identified landform elements in the Northern Mixed Prairie range type in central Saskatchewan. The amount of forage produced by plants is an indicator of the effects of herbage removal on the subsequent efficiency of forage production. It was assumed that plants had recovered from herbage removal when current year standing crop was not different ($P \leq 0.05$) from an unmowed control. An additional assumption was that forage production and current year standing crop by unmowed control plants represents the potential for that species or species group, and any limitations in production or current year standing crop can be attributed to herbage removal. This assumption appears valid because in no instance was above ground net primary production enhanced by mowing. In only 9 of 1,620 comparisons (3 comparisons for *Festuca hallii*, 2 comparisons for *Stipa curtiseta*, 3 comparisons for other graminoids, and 1 comparison for forbs and shrubs) was current year standing crop greater after herbage removal than in the control. In all other comparisons (1,611) with the unmowed control, current year standing crop was either reduced or unaffected by herbage removal. These responses in above ground net primary production and current year standing crop are strong indications that increases in herbage production should not be expected ($P \leq 0.05$) after grazing in the Northern Mixed Prairie range type in central Saskatchewan.

Recovery of potential plant production after mowing varies among plant species or species groups, landform elements and times of mowing. In some cases the production potential of plants recovered in the year of mowing, in other cases plant production potential recovered the growing season following mowing, and in other instances the potential production of plants did not completely recover until the second full growing season after mowing. The following guidelines are based on plant growth after herbage removal and they will prove useful in developing grazing systems in the Northern Mixed Prairie range type in Saskatchewan to maintain the production potential of native forages.

Current year standing crop of *Agropyron dasystachyum/A. smithii* recovered in the year of mowing or in June of the following year, with the slowest recovery of current year standing crop occurring on the level upland landform element. This pattern of recovery of current year standing crop suggests that a grazing system (e.g. rotation or deferred rotation grazing) that includes grazing of paddocks each year should allow *Agropyron dasystachyum/A. smithii* to regain their production potential after removing herbage.

Stipa curtiseta current year standing crop after mowing in April or May was similar to the control by June, and except for the south aspect-convex slope, current year standing crop was similar to the control in July when mowed in June. When mowed in July, August, September, October or November current year standing crop equaled the control in June of the next year. Together these responses suggest that *Stipa curtiseta* can be grazed each year (e.g. rotation or deferred rotation grazing) without compromising current year standing crop.

Current year standing crop for graminoids other that *Agropyron dasystachyum/A. smithii*, *Festuca hallii* and *Stipa curtiseta* generally recovered within 1 to 3 months of being mowed in April, May or June. Current year standing crop was similar to the control by June of the next year when mowed in July, August, September, October or November. It would therefore appear that other graminoids may be grazed each year (e.g. rotation or deferred rotation grazing) while maintaining current year standing crop.

Current year standing crop of forbs and shrubs usually recovered within 1 to 3 months after mowing in April, May or June, and by June of the next growing season when mowed in July, August, September, October or November. This pattern of regrowth after mowing implies that a grazing system (e.g. rotation or deferred rotation grazing) that allows grazing every year will not reduce current year standing crop of forbs and shrubs.

Festuca hallii appears sensitive to herbage removal because this high producing grass has the widest ranging and longest recovery of current year standing crop. On all landform elements except the south aspect-concave slope landform element, current year standing crop recovered to levels comparable to the control during the same growing season when mowed in April or May. In other situations, current year standing crop recovered in June or July the year after mowing. Recovery of current year standing crop required a full growing season after mowing, most notably on the contrasting south aspect-concave slope and north aspect-concave slope landform elements. The variable and relatively long time for recovery of *Festuca hallii* implies that a grazing system (e.g. rest rotation grazing) that incorporates a complete year of rest after grazing would be required to ensure that this high producing grass recovers it's production potential before being grazed again. If a year of full rest after grazing is not incorporated into a grazing system, it is predicted that the production and abundance of *Festuca hallii* will decline because this grass appears the most sensitive to herbage removal among the species studied.

Total current year standing crop is the sum of all plant species and species groups. Total current year standing crop was similar to the control the year of mowing or the year after mowing on the north aspect-concave slope, north aspect-convex slope and the level upland

landform elements. In contrast, total current year standing crop recovered in August of the first full growing season on the south aspect-concave slope landform element and in June or July in the next year. If the desire is to maintain total forage production over the entire landscape, these patterns of plant growth after mowing suggest that a grazing system such as rest-rotation grazing, that incorporates a full year of rest after grazing would be needed to allow plants to recover their production potential. If a full year of rest is not provided after grazing, it is predicted that that total forage production will decline over the entire landscape.

In summary, this research suggests that sustainable grazing of the Northern Mixed Prairie range type in central Saskatchewan will require that complete rest for at least 1 full growing season the year after grazing is provided if potential forage production is to be realized over the entire landscape and overgrazing is to be prevented (see Romo 2001). These recommendations should serve as guiding principles for developing grazing systems, however, these guidelines may require modification for site-specific conditions and management objectives.

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